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2 PHYSICAL AND HYDROLOGIC COMPONENTS

2.1 TOPOGRAPHY AND LAND USE

The primary non-calibrated static terms used in the SFWMM are topography and land use. The data input to the model for these components is considered to be constant throughout the period of simulation. While much of the topography data used in the model was developed under previous versions, several new data sets were available for SWFMM v5.5. The topography update process and results are provided in this section. The land use section describes the types of land covers available for simulation in the model and includes aerial photographs which show the relative differences between some of the more unique land cover types.

2.1.1 Topography

Topography data sources as utilized in the SFWMM are illustrated in Figure 2.1.1.1. The newer data sets used in updating SFWMM v5.5 covered the EAA and the natural areas to the south of the EAA. Other sources of data came from a variety of sources and represented the best available data from past years where metadata were not generally recorded. The sources of the older topography data will be discussed at the end of this section.

After considering existing documentation, spatial location, and quality of several new topography datasets, five datasets were selected for incorporation into this update. Additionally, it was decided to uniformly lower the elevation of the Everglades Agricultural Area (EAA) based on a uniform subsidence rate. The EAA has several factors which cause rapid subsidence, most importantly aerobic microbiological decomposition (oxidation). Measured rates of subsidence (Shih et al., 1997) were used to determine a rate of subsidence in the EAA for the last decade. The Holey Land and Rotenberger Wildlife Management areas were excluded from this subsidence adjustment. The new datasets are:

1. *High-Accuracy Elevation Data collection from the United States Geological Survey (USGS).* This data consists of elevation values on a regular grid of 400 meters, throughout the Everglades National Park (ENP) and portions of southern Miami-Dade County. Data in the western limits of the ENP have not been collected or finalized. The data was collected in the North American Datum 1983 (1990) NAD83(90) horizontal datum and the North American Vertical Datum 1988 (NAVD88) vertical datum. The stated vertical accuracy is 0.5 feet.
2. *LIDAR (Light Detection and Ranging) elevation data collected for Water Conservation Area (WCA) 3A, north of Interstate 75 (I-75).* This data was contracted by the USGS to EarthData International, Inc. The raw data was re-sampled to 5-meter pixels and processed by the contractor, using proprietary algorithms, to represent bare-surface elevation. The stated vertical accuracy is 15 centimeters, or ~ 0.5 ft.
3. *The Rotenberger Wildlife Management Area Survey, 1999.* This survey was conducted by Lindahl, Browning, Ferrari, and Hellstrom, Inc. Using Global Positioning Survey (GPS) technology and airboats, six east-west cross-sections were traversed, with elevations collected at approximately 0.25 mile spacing. The reported vertical accuracy of this data is 0.2 feet.
4. *The Stormwater Treatment Areas (STAs) 1990s.* These elevations were compiled by the

Everglades Construction Project (ECP) and are based upon the best available data. The only data available are mean elevations for the STA cells.

5. *The 8.5 Square-Mile Area Survey, 1986.* This area was surveyed by Aero-metric Corporation under contract to the United States Army Corps of Engineers (USACE), from January to April 1986. Elevations were collected on a 300-foot grid using conventional methods. The purpose of the survey was to produce cross-sections for hydrologic modeling. The vertical accuracy is reported to be 0.1 meter, or ~ 0.33 ft.

Other sources of data that were not used fell into two categories: not within the model domain or not appropriate to natural surface elevation modeling. The first category is clear; examples of the second category are as follows:

- *The LIDAR data collected by the USACE along and to the east of the levee separating the urban area of South Florida from the Everglades.* This data covered a relatively small area in comparison to the voluminous amount of data it contained. Also, it was not collected with regional-scale hydrology in mind, which seeks to represent the elevation of the natural terrain as opposed to man-made features such as roads and levees. Consequently, this data was not incorporated into the current elevation update.
- *The Truck Survey and the Airboat Survey conducted as part of the USGS High-Accuracy Elevation Data Collection.* These surveys were conducted differently from the more comprehensive Helicopter Survey (which represents the bulk of the collection). The documentation on these sets is sparse, and they were conducted in the urban portion of Miami-Dade County. An analysis of the data shows that the Truck Survey in particular did not target natural ground elevation specifically. For these reasons, the datasets were excluded.

The High-Accuracy Elevation Data (2001) collection was created using GPS technology in conjunction with numerous vehicles, including helicopter, truck, and airboat platforms. The portions of this dataset east of the levee were excluded. The eastern area was collected primarily by airboat and truck platform, while the helicopter technique was used almost exclusively west of the levee (Figure 2.1.1.2). Examination of the data showed that the data east of the levee was inconsistent with other data sources and would not be used. The data west of the levee was determined to be of good quality because it was consistent with existing knowledge and used a logical and defensible method of collection. The processing of this dataset involved the following steps:

- Converting the vertical datum from NAVD88 to National Geodetic Vertical Datum 1929 (NGVD29) using the VERTCON 2.0 program provided by the National Geodetic Survey.
- Projecting to Florida State-Plane East feet using Arc/Info.
- Masking out the roads and canals using the SFWMD major canals coverage buffered 50 feet, and the ETAK major roads (1994) buffered by 50 feet. The ETAK roads (produced by Etak Inc., a leading publisher of digital street map databases) were chosen because of the higher locational accuracy of the linework. The SFWMD has newer road coverages, which are considered better in attribution.
- Projecting the horizontal data from Universal Transverse Mercator (UTM) to Geographic (Lat-Long) using the Arc/Info 'project' command (VERTCON 2.0 requires Lat-Long coordinates).

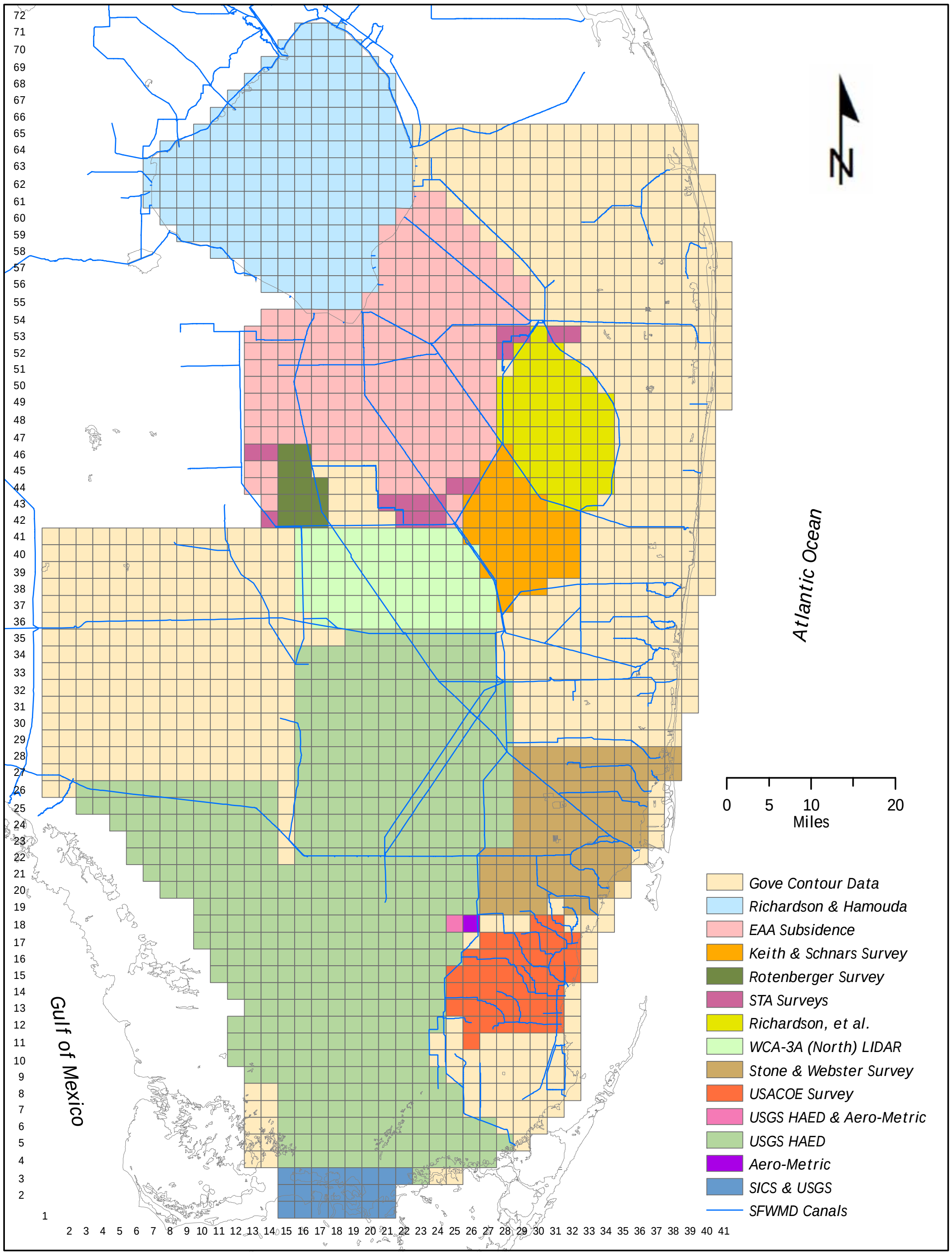

Figure 2.1.1.1 Sources of Topography for SFWMM v5.5

- Aggregating the remaining data to the SFWMM cells by averaging the points that fell within each cell. The process produced an average of 61 points per cell, ranging from 9 to 98 points with a standard deviation of 9. The SFWMM cells containing relatively few points were located on the fringe of the model and were excluded from the final values provided.

- Calculating and removing outlier data points per SFWMM cell based on a value being ~2 standard deviations from the mean value for the cell. These values are man-made features or localized features not representative of natural ground elevation.
- Updating 356 cells in the SFWMM.

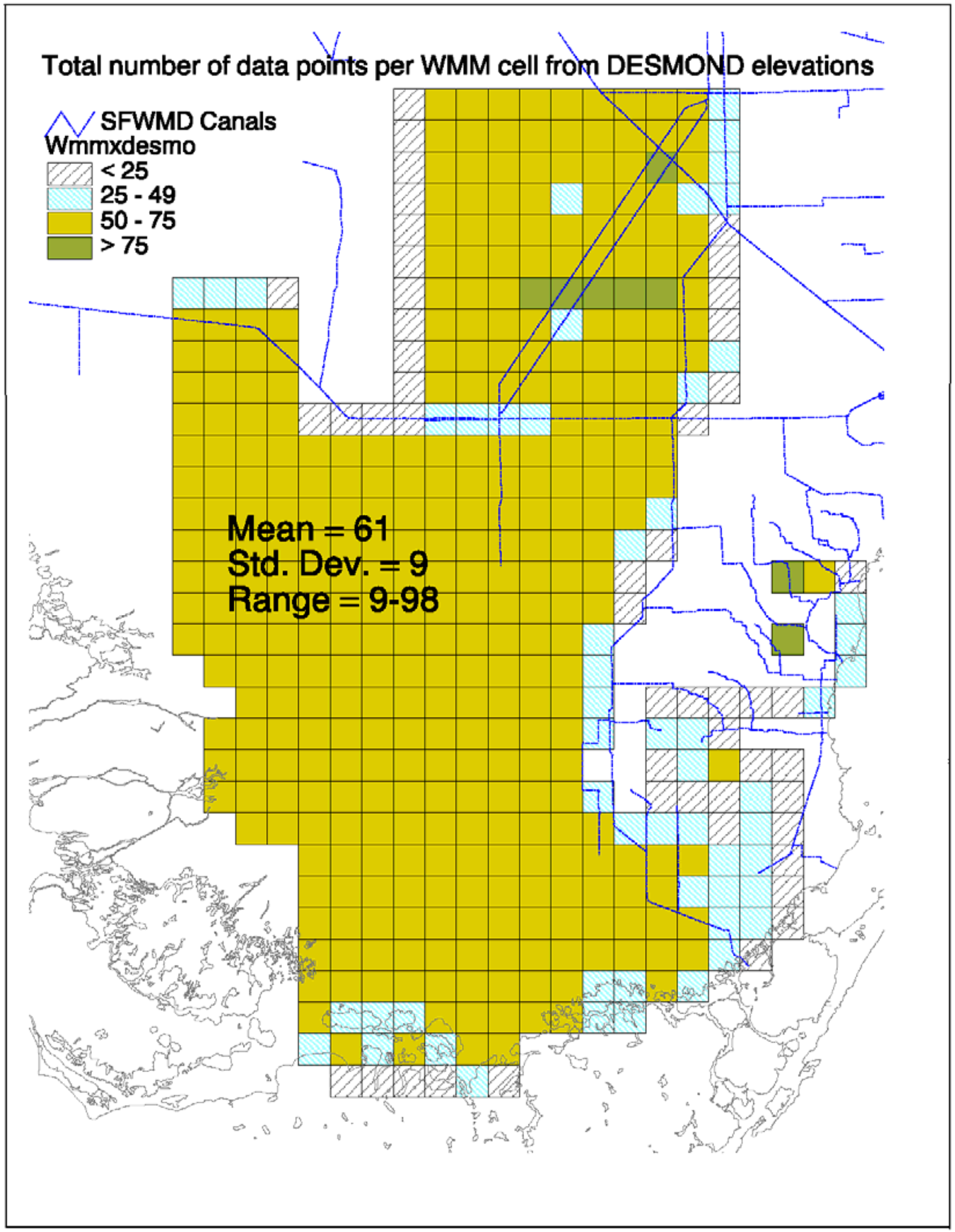

Figure 2.1.1.2 Total Number of Data Points per SFWMM Cell for the High-Accuracy Data Collection

The WCA-3A LIDAR Data was masked to exclude areas outside of the natural internal portion of WCA-3 north of I-75. An analysis of the data showed some abnormal variance in the data moving north-south, but it was determined that for regional-scale modeling, this variance would be aggregated out of the data. In the majority of SFWMM cells, over 400,000 points of LIDAR elevation data were aggregated to one value (Figure 2.1.1.3). The processing of this dataset involved the following steps:

- Masking out the roads and canals using the SFWMD major canals coverage buffered by 50 feet, and the ETAK major roads buffered by 100 feet, except for I-75 which was buffered by 150 feet. The final mask eliminated all data outside of the internal buffer distance, although some data points had been collected outside of the conservation area.

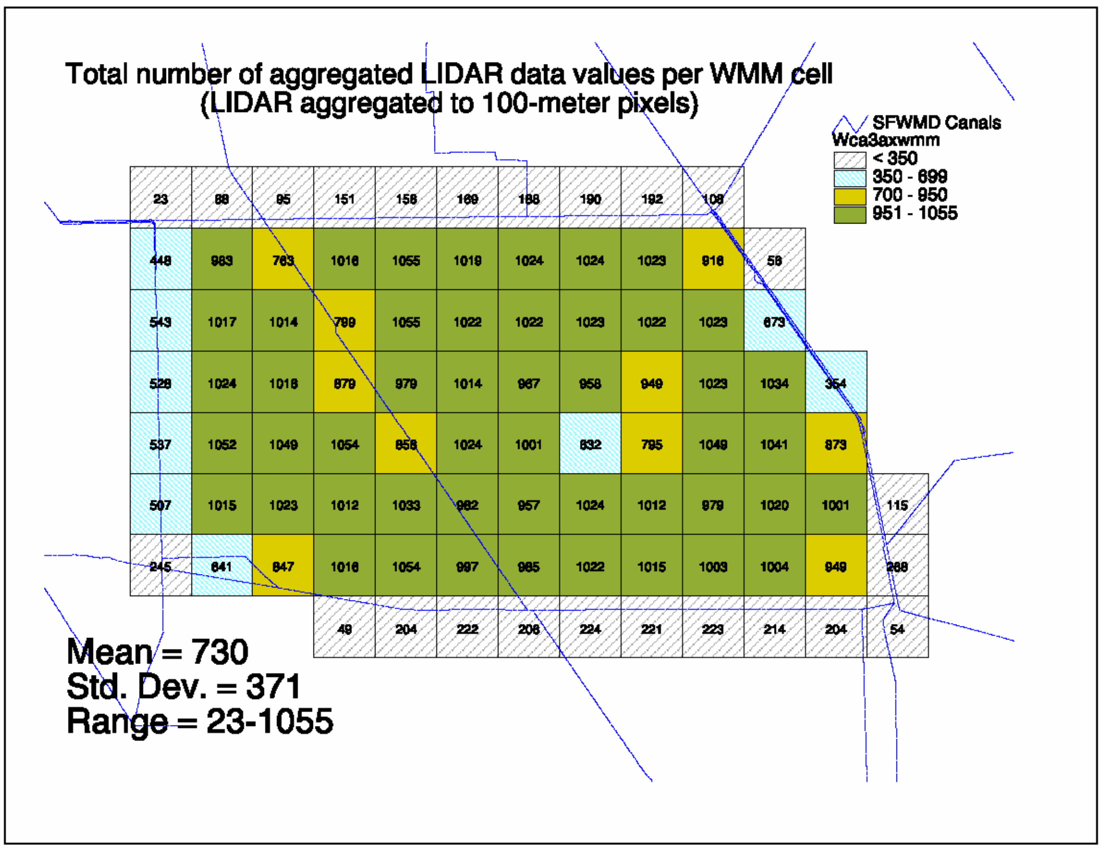

Figure 2.1.1.3 Total Number of Data Points per SFWMM Cell for the USGS LIDAR data

- Aggregating the data to 100-meter pixels from the original 5-meter pixels that were received.
- Projecting the data from UTM to Geographic (Lat-Long) projection.
- Converting the vertical datum from NAVD88 to NGVD29 using the VERTCON 2.0 program released by the National Geodetic Survey.
- Projecting the horizontal data from Geographic to Florida State-Plane East feet using the Arc/Info 'project' command.
- Converting the elevation from meters to feet.
- Aggregating the remaining data per SFWMM cell by averaging the values that fell within each cell. The process produced an average of 730 points per cell, ranging from 23 to

1,055 points with a standard deviation of 371. Some SFWMM cells along the fringe of the dataset were excluded from the final values provided.

- Calculating and removing outlier data points per SFWMM cell based on a value being approximately 2 standard deviations from the mean value for the cell. These values are man-made features or localized features not representative of natural ground elevation. For the WCA-3A LIDAR, a manual approach was taken to retain "patches" of outlier points that could represent a large-scale natural feature. Only points which were randomly spaced were removed.
- Updating 68 cells in the SFWMM

The EAA was determined to be subsiding at a long-term average rate of between 1 and 1.2 inches per year (Ingebritsen et al., 1999). These rates of subsidence are consistent with Stephens and Johnson (1951), Shih et al. (1979), and Stephens et al. (1984). In the previous revision of elevation data for the SFWMM, a rate of 0.1 foot per year was applied to the 1960 USACE 1-foot contour map data for 28 years (1960-1988) to achieve what became the 1990 updated SFWMM topography (Gove, 1993). According to Shih et al. (1997) subsidence since 1978 has occurred at an average rate of 0.57 inches per year. Measured rates ranged from 0.31 to 0.77 inches per year. In spite of the limited area from which subsidence measurements were taken, and the lack of a clear pattern of subsidence, the average rate of 0.57 inches per year was applied to all EAA cells (123 SFWMM cells) for ten years (1990-2000) to arrive at a current elevation value (Figure 2.1.1.4). Note that the Holey Land and Rotenberger Wildlife Management areas were excluded from this update. Both of these areas are managed differently from the rest of the EAA and each other (Smith, 2001). Both areas were surveyed with conventional methods in 1992 by the Florida Game and Freshwater Fish Commission (FWC) and updated in the SFWMM.

For the Rotenberger Wildlife Management Area Survey (1999), corresponding SFWMM cells were updated based on the surveyed data and a manually devised weighting mechanism (Brion, 2001). Thirteen SFWMM cells were updated.

The STA elevations were drawn from design dots and/or construction plans. The current information available consists of mean elevations for the cells of each STA. The sorbnd_1000 and STA levee coverages were used to create a coverage representing the STAs. The mean elevations were then applied to the appropriate STA cells. A weighted average elevation per SFWMM cell was created using the elevations from the STA cells and SFWMM v3.7 elevations for portions of SFWMM cells not covered by an STA. Seventeen cells in the SFWMM were updated.

For the 8.5 Square Mile Area Survey (USACE, 1999), remaining elevations were averaged for one SFWMM cell, Row Column (18, 26). Elevation points collected along the L-31 Levee were manually removed. These values were approximately 6 feet higher than the rest of the data.

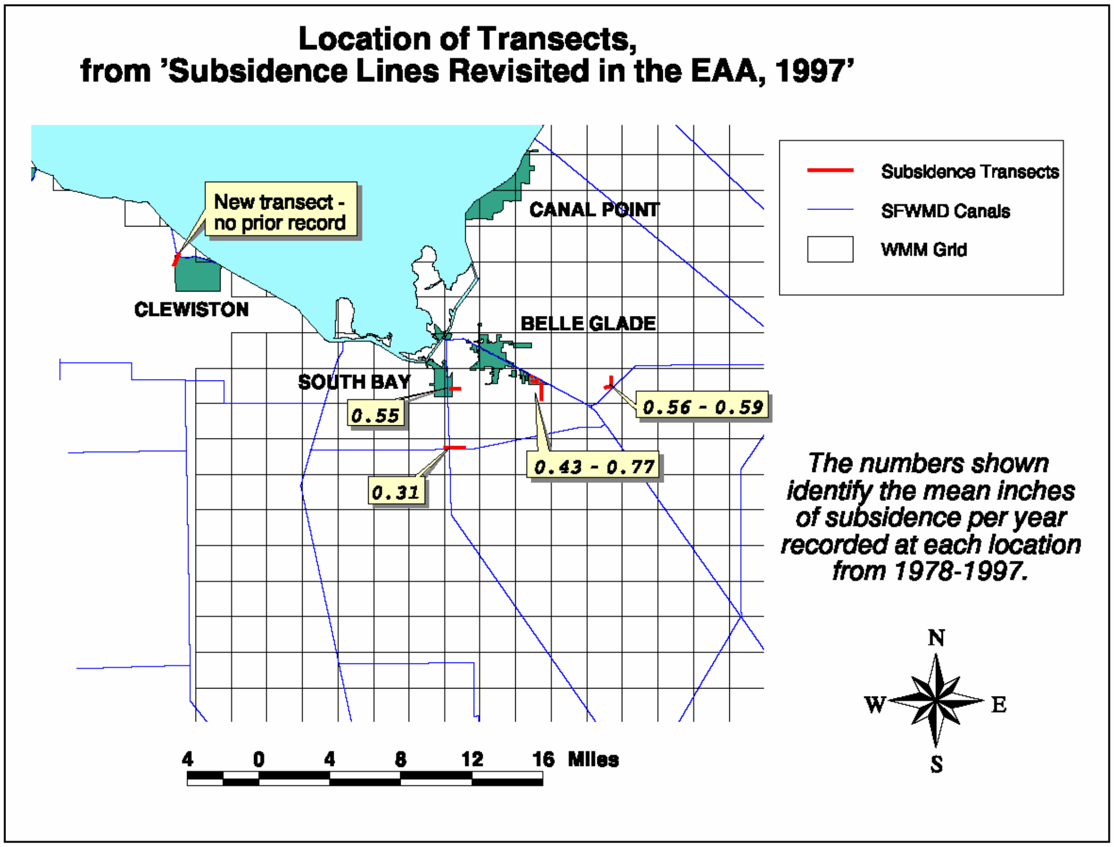

Figure 2.1.1.4 Location of Transects of Measured Subsidence in the EAA (Shih et. al., 1997)

Older Data Sources

There were six data sets used to construct the topography in areas not replaced by new information. These data sets are considered to be legacy information and are not addressed in detail in this documentation. The sources for the data are:

1. For the BCNP and parts of Broward, Palm Beach and Martin Counties, a memorandum for Charles Gove, dated November 11, 1993 was used. The source included both one-foot and five-foot contour data.
2. For WCA-2A, a data survey by Keith and Schnars, dated April 2, 1993, and titled GPS Topography Survey of WCA-2A.
3. For Lake Okeechobee, the source was a report from J. R. Richardson and E Hamouda titled "BIS Modeling of Hydroperiod, Vegetation, and Soil Nutrient Relationships in the Lake Okeechobee Marsh Ecosystem," Arch. Hydrobiol., Advances in Limnology, 45, 95-115, 1995.
4. For WCA-1, the source was a report from Richardson, et al., "An Evaluation of Refuge Habitats and Relationships to Water Quality, Quantity, and Hydroperiod." 1990.
5. For North Miami-Dade, the data was based on an undated survey from Stone and Webster.
6. For South Miami-Dade, the data was based on an undated survey from USACE.

Figure 2.1.1.5 displays the final elevations for the SFWMM. More information on the update process for the new topography is provided in Appendix M.

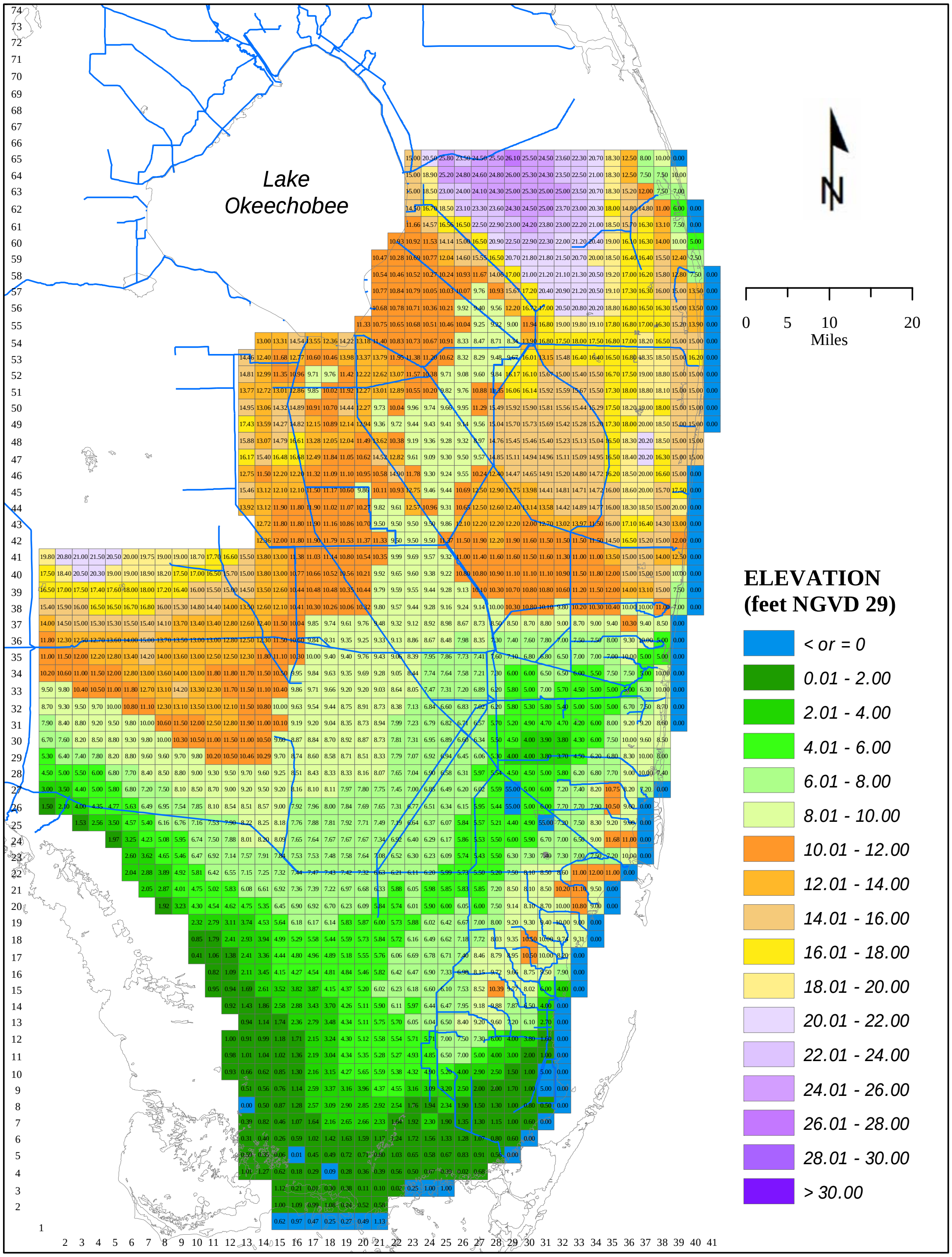

Figure 2.1.1.5 SFWMM v5.5 Grid Cell Elevation Values

2.1.2 Land Use

This section describes the South Florida Water Management Model (SFWMM) land use or vegetation developed to represent the years 1988, 2000 and 2050 for each 2-mile by 2-mile model grid cell. The 1988 land use map is required for calibration purposes, while the 2000 and 2050 maps help to illustrate the changes between current and future representation of the South Florida system in the model. The final maps are shown in Figures 2.1.2.1, 2.1.2.2 and 2.1.2.3 for 1988, 2000, and 2050. An effort was made to use the most recent or most accurate data. Since no detailed, uniform map of vegetation exists for the entire SFWMM area several data sources were used to create a composite high resolution Geographic Information System (GIS) dataset to represent the year 2000. The data sources for the vegetative classes and the locations of the datasets are shown in Figure 2.1.2.4. The land use cover classification was expanded for SFWMM v5.5 (a "crosswalk" of the old classification to the updated classification is provided in Appendix T). Helicopter flights were used to visually check the natural areas, and photographs are included to illustrate the new classification scheme. This section also describes the sources of data and a description of each land use class is provided with emphasis on its hydrological differences. Values for overland flow resistance coefficients and evapotranspiration (ET) parameters from the calibrated version of the SFWMM v5.5 are provided in Table 2.4.2.1 within Section 2.4.2.

Sources and Classification Method

2000 Land Use

The Florida Land Use and Cover Classification System (FLUCCS) is the primary source for land use/land cover input to the SFWMM. Since FLUCCS does not include detailed vegetation information, the best available alternative data sources were used for vegetation classification within the Water Conservation Areas and Everglades National Park (Figure 2.1.2.4). A composite GIS coverage of these sources was developed and intersected with the SFWMM grid in order to produce a majority land use type for each cell. Checks were performed including a visual check against 2000 satellite imagery to evaluate each grid cell's former and new land use class. In areas where the majority land use type from the land use data did not match the satellite image, the satellite image took precedence. A draft SFWMM 2000 land use map was verified by aerial survey resulting in adjustments to several classifications in the natural areas and parts of the Everglades Agricultural Area.

1988 Land Use

The SFWMM 2000 land use map was used as a base for revision of the 1988 land use map. It was assumed that natural areas in 2000 were also natural areas with the same land use type as in 1988. Urban and agricultural cells in the earlier version of the 1988 land use map and the SFWMM V5.5 2000 land use map were cross checked. Cells designated as agricultural in the original 1988 map, and as urban in the 2000 map, reverted to agricultural in the revised 1988 map. A check of urban cells was also performed.

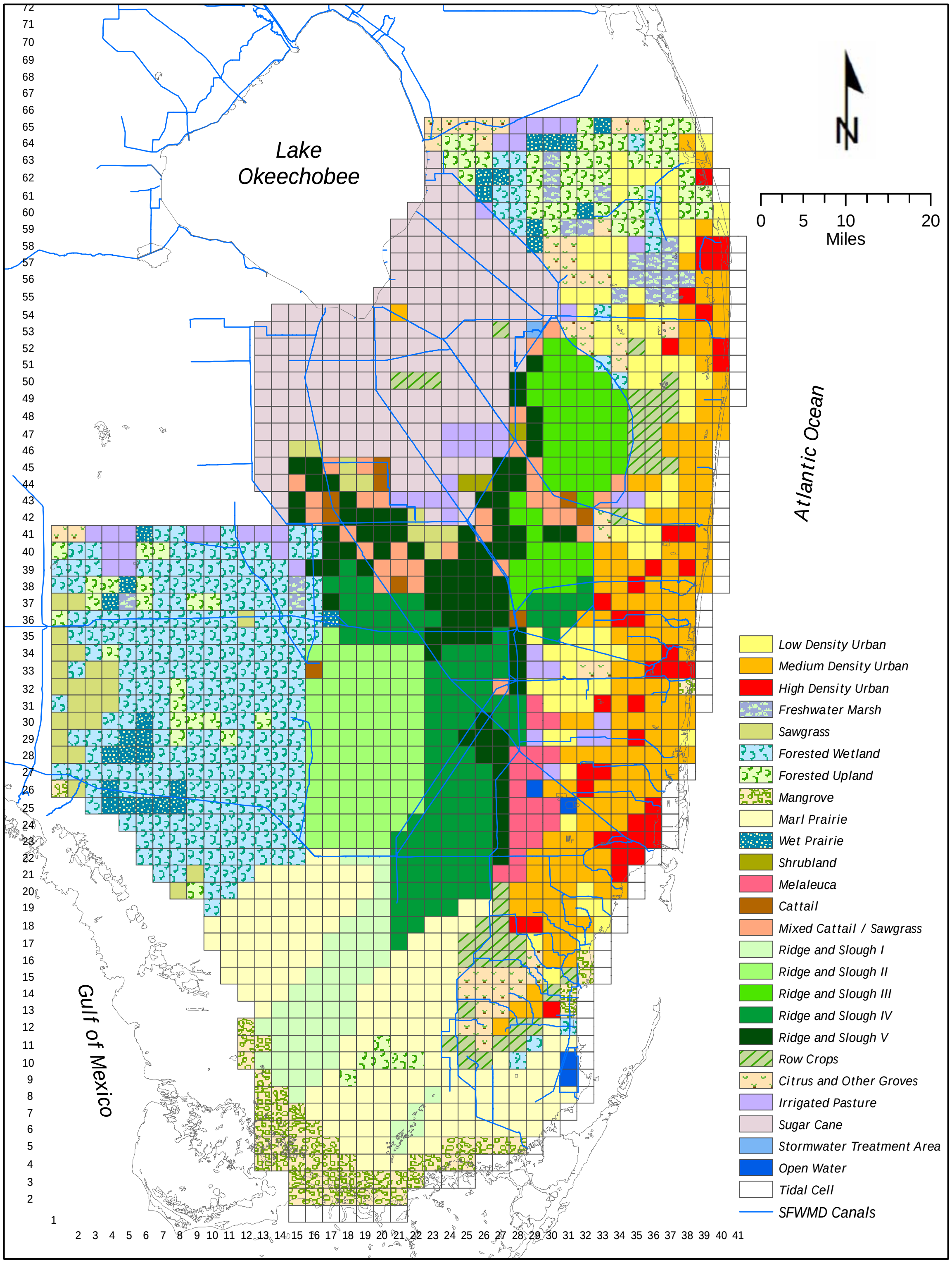

Figure 2.1.2.1 1988 Land Use Map

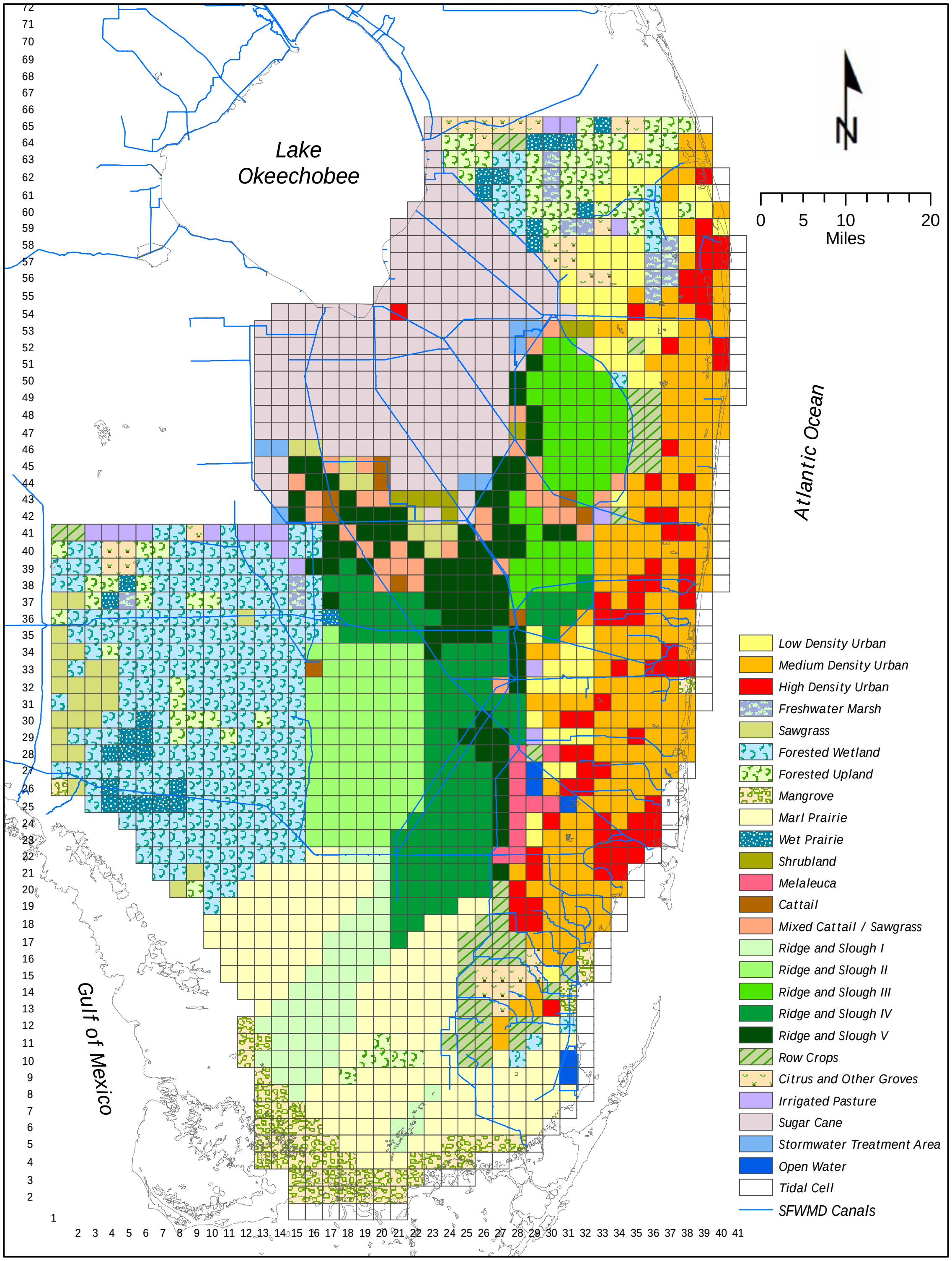

Figure 2.1.2.2 2000 Land Use Map

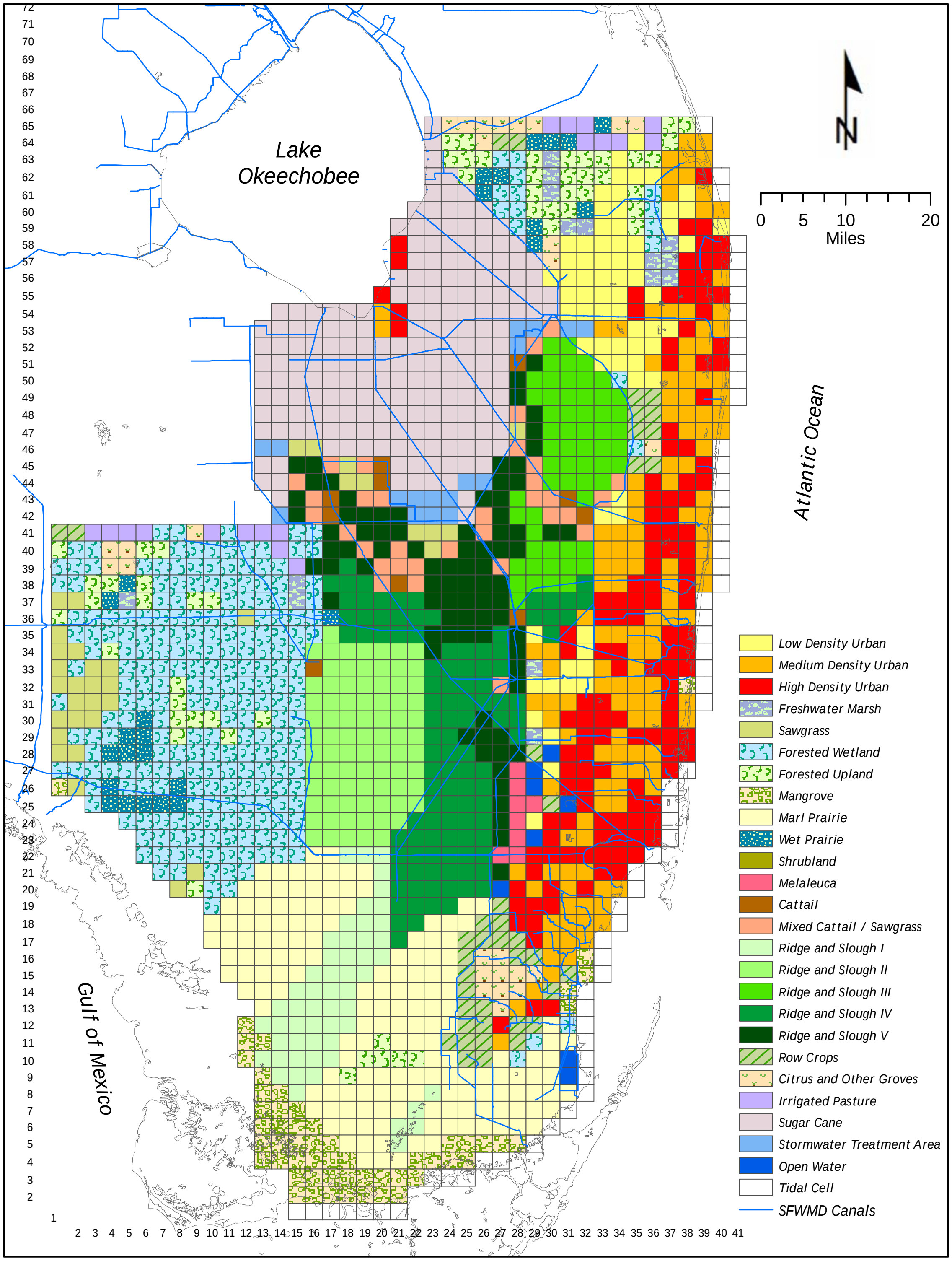

Figure 2.1.2.3 2050 Land Use Map

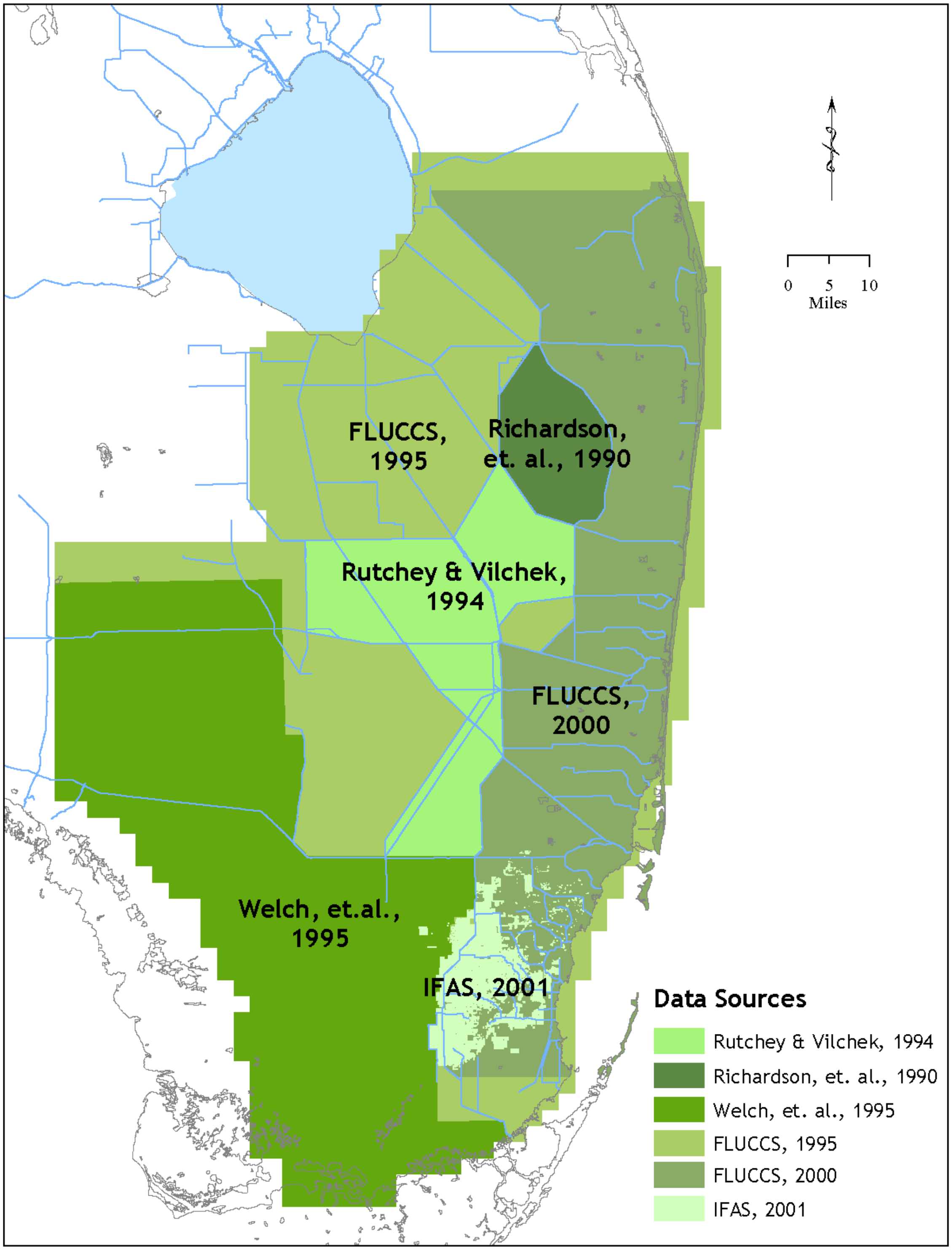

Figure 2.1.2.4 Data Source for Vegetative Classes

2050 Land Use
The 2000 land use coverage was used as a starting point for the 2050 land use projections. All polygons with the potential to be developed were extracted from the 2000 land use coverage. These polygons were then updated with Comprehensive Plan projections from Palm Beach, Broward and Miami-Dade counties. The 2050 land use coverage was then intersected with the SFWMM grid and the majority land use was assigned to each grid cell. The natural areas were assumed to be the same as 2000 except in areas of urban development. Land use updates for Martin County were included which changed the projections for six of the SFWMM cells (R64C32, R64C33, R64C34, R64C36, R65C32, and R65C36 were all changed from Forested Upland to Irrigated Pasture).

Land Use/Landscape Description

This section will outline all of the land use classifications available within the gridded extent of the SFWMM. The model can only accept one land use classification per grid cell and the associated assignment is assumed to apply over the entire spatial extent of the cell. This assumption is reasonable in a majority of the model domain where changes in landscape occur gradually. In the Lower East Coast Service Areas, where land use can change more rapidly from urban to agricultural to natural classifications, additional consideration is made for land use variability at a scale smaller than a 2-mile by 2-mile grid cell. This is accomplished as part of a pre-processed sub-module within the SFWMM, known as the ET-Recharge model. The details related to this feature are explained in Section 2.3.5. The SFWMM classifies land use as one of the following choices:

High Density Urban
Model grid cells with greater than 50 percent impervious cover. Areas comprised of industrial sites, shopping centers with large paved areas, and high density residential areas are designated as high density urban.

Medium Density Urban
Model grid cells with 25 to 50 percent impervious cover. Medium density residential areas or mixtures of low density and high density within the same grid cell are classified as medium density urban.

Low Density Urban
Model grid cells with less than 25 percent impervious cover. This category includes golf courses, small holdings and low density residential areas; it may also contain agricultural or natural areas within urban land uses.

Ridge & Slough
The most extensive landscape in the remnant Everglades, Ridge and Slough, can be characterized as a mosaic of sawgrass ridges interspersed with open water sloughs and dotted with tree islands. Ridges vary from consisting only of sawgrass, to ridges with shrub cover or tree islands. Slough conditions range from open water to dense aquatic vegetation cover (e.g. water lilies). Periphyton communities are established to varying degrees in some areas. Due to shortened hydroperiods, sawgrass and other macrophyte encroachment into sloughs has resulted

in an increased resistance to flow. The ridge and slough landscape is highly directional in places (Central WCA-3A), and has non-directional characteristics in other places (WCA-1). Because of the uniqueness of ridge and slough landscape habitat, some aerial photographs are included.

Due to water management practices, the current Ridge & Slough landscape is a modified form of the pre-drainage Everglades landscape. It is reduced in spatial extent as well as modified in terms of vegetation community composition. For the purpose of SFWMM land cover classification, current vegetation occurring within the boundary of Ridge and Slough landscape as defined in the Natural System Model, was classified as (modified) Ridge and Slough, and divided into five categories representing different resistances to flow.

Ridge & Slough I consists of linear directional sawgrass ridges interspersed with predominantly open water sloughs. This subclass of Ridge & Slough has lower resistance to flow than other Ridge & Slough subclasses because it has more open water with fewer water lilies, little to no invasion of the sloughs with sawgrass and other species and little periphyton. The Ridge & Slough I landscape is found in Shark River Slough and Taylor Slough in Everglades National Park.

Ridge & Slough II is comprised of directional sawgrass with open water sloughs that have been slightly filled in with sparse sawgrass and other species, increasing resistance to flow. Periphyton growth on submerged stems of the emergent vegetation in the sloughs increases flow resistance. The Ridge & Slough II landscape is found in WCA-3A south of Alligator Alley and west of the Miami Canal (Figure 2.1.2.5).

Ridge & Slough III is predominantly non-directional consisting of circular and irregular shaped sawgrass ridges interspersed with open water sloughs. Shrubs and trees are present on many of the ridges. In places, water lilies are present in the sloughs. Ridge & Slough III is found in WCA-1 and WCA-2A (Figure 2.1.2.6). Resistance to flow is expected to be higher than Ridge and Slough II due to lack of directionality.

Ridge & Slough IV consists of non-directional to slightly directional sawgrass ridges with little evidence of shrubs or tree islands. Sloughs often have water lilies or periphyton in them. Areas of Ridge & Slough IV include WCA-2B, parts of WCA-3A north of Alligator Alley and southeast of the Miami Canal / Alligator Alley intersection, WCA-3B and Northeast Shark River Slough (Figure 2.1.2.7).

Ridge & Slough V consists of Ridge & Slough vegetation that has been considerably modified by in-filling of sloughs with sawgrass and other wet prairie species. Resistance to flow is higher than the other Ridge & Slough subclasses and slightly less than that of the sawgrass landscape. Areas of Ridge and Slough V include parts of northwest and northeast WCA-3A, parts of the Rotenberger and Holey Land Wildlife Management Areas, northern WCA-3B and the Pennsuco wetlands (Figure 2.1.2.8).

Figure 2.1.2.5 Examples of Ridge & Slough II Landscape

Figure 2.1.2.6 Examples of Ridge & Slough III Landscape

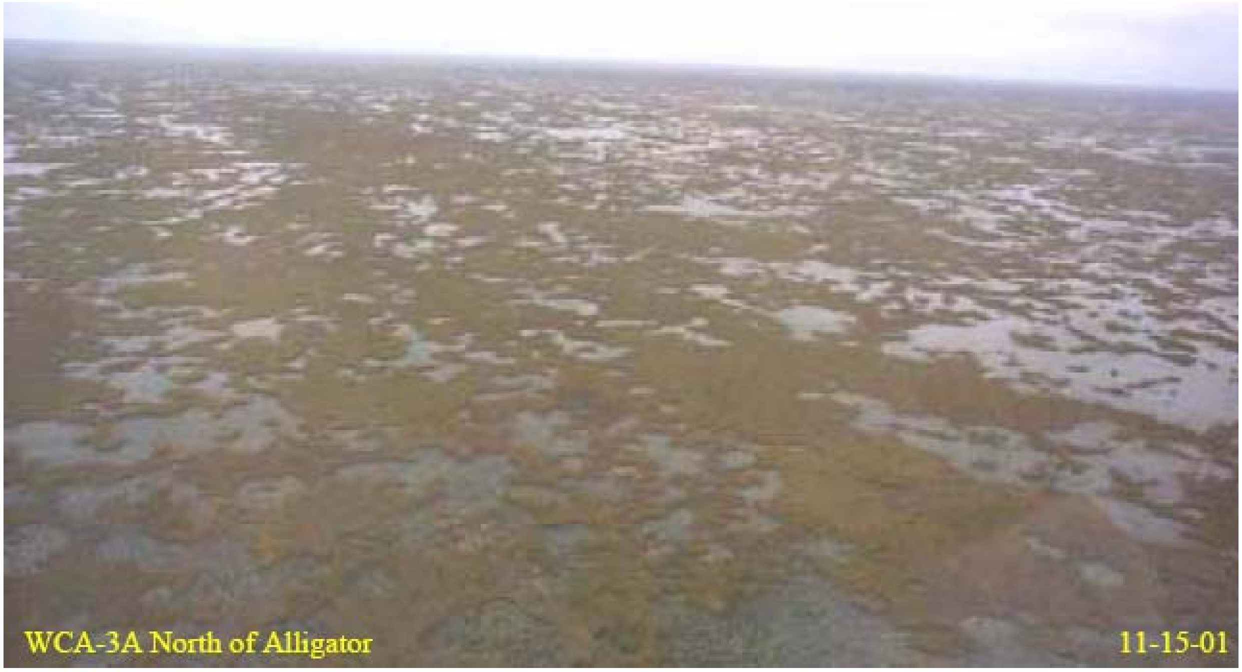

Figure 2.1.2.7 Examples of Ridge & Slough IV Landscape

Figure 2.1.2.8 Examples of Ridge & Slough V Landscape

Freshwater Marshes
Freshwater marshes are inundated areas outside of the Ridge & Slough boundary. Marshes are dominated by emergent and floating vegetation. Freshwater marshes occur in deeper depressions than prairies and have longer hydroperiods.

Wet Prairie
Wet prairie landscape is found in shallow depressions among flatwoods, in pastures, and at the edges of cypress domes and marshes. In this classification, wet prairie is a grassy landscape

mixed with open water. The dominant vegetation of wet prairies include wiregrass, spike rush, muhly grass, beak rush, cordgrass, maidencane, and St. John's wort.

Marl Prairies
Marl Prairies are comprised of relatively (compared to Ridge & Slough landscapes) sparse, low stature sawgrass on marl soils. Open water sloughs with no prominent directional pattern occur in marl prairies. The Marl Prairie landscape was defined by intersecting model grid cells with predominantly sawgrass vegetation and marl soils. The resulting Marl Prairies correspond closely with those identified in several studies (Davis 1943, Davis et al, 1994, McVoy and Park 1997) as having a distinct boundary with the Ridge & Slough landscape. Resistance to flow in the Marl Prairies is lower than in the Ridge & Slough landscapes because of the relatively sparse sawgrass.

Sawgrass
Sawgrass classification is applied to areas outside of the Ridge & Slough boundary that are dominated by contiguous areas of medium to dense sawgrass. In some places there are breaks in the sawgrass due to open water where periphyton and bladderwort may be found.

Cattail
Cattail (Typha spp.) is a marsh species that thrives under high-nutrient conditions. It occurs naturally in disturbed areas or around gator holes and can be found downstream of the Everglades Agricultural Area in areas where nutrient enrichment has occurred.

Mixed Cattail and Sawgrass
Mixed cattail and sawgrass is a mixture of cattail patches and sawgrass (Figure 2.1.2.9) and is used to represent SFWMM grid cells that contain greater than 20 percent cattail and greater than 20 percent sawgrass. It is found in areas where cattails have invaded sawgrass, such as parts of northern WCA-3A and along parts of the edges of WCA-2A and the Loxahatchee National Wildlife Reserve.

Figure 2.1.2.9 Example of Mixed Cattail and Sawgrass Landscape

Stormwater Treatment Areas

Stormwater Treatment Areas include large, constructed, treatment wetlands designed to serve as biological filters to reduce the phosphorous concentration in agricultural runoff entering the Everglades Protection Area. Vegetation varies by STA, and consists mainly of cattail, mixed marsh and submerged aquatic vegetation communities.

Forested Wetlands

Forested wetlands include cypress swamps, hardwood and wetter species forming a mosaic of pine flatwoods and depressed wetlands.

Forested Uplands

Forested uplands are pinelands on higher sands or areas of former mosaic of pine flatwoods and depressed wetlands that have been dehydrated by artificial drainage.

Mangrove Forests

Mangrove forests are coastal landscapes containing red, white or black mangrove that may extend inland such as in the southern and southwestern Everglades. Mangroves are permanently to regularly flooded by tidal waters.

Mangrove Forests

Melaleuca is an exotic species (Melaleuca quinquenervia) forming monotypic stands that dominate the landscape. Melaleuca exists in both upland habitats, and lower areas which have experienced prolonged inundation.

Shrubland

Shrubland includes areas where trees are not present but shrubs are the dominant vegetation. Shrubs may include: Brazilian pepper, wax myrtle and saw palmetto. Shrubland is an upland community which rarely experiences inundation.

Open Water Bodies

Open water bodies such as lakes, canals or deep excavated reservoirs are included in the open water category.